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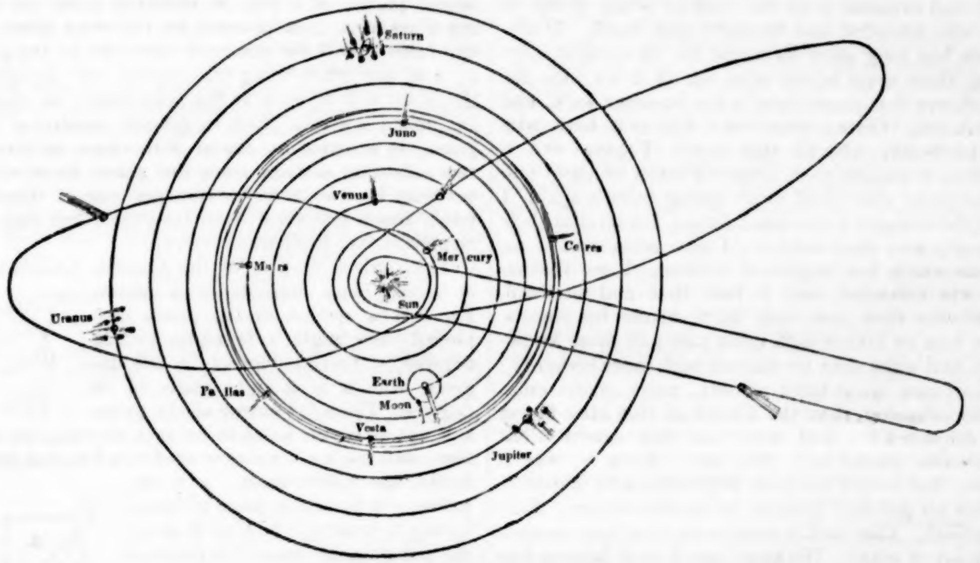
## POPULAR ASTRONOMY. PART I.




THE SOLAR SYSTEM.

### INTRODUCTION.

"WHEN I consider thy heavens, the work of thy fingers; the moon and the stars, which thou hast ordained;—what is man, that thou art mindful of him? and the son of man, that thou visitest him?"——Psalm viii., 3, 4.

When the inspired Psalmist gave utterance to these words, he was evidently under the influence of those feelings of awe, wonder, and admiration, which are sure to be excited in every intelligent mind, by the splendid and sublime phenomena presented to us by the heavenly bodies. When we consider the magnitude and the number of those bodies, the immense distances which separate them one from another, the almost inconceivable velocity with which they move, and that those which we can see form, probably, but a very small part of the whole number;—when we revolve these things in our minds, we are naturally brought to reflect on our own insignificance in the grand scheme of creation. If a man, after having applied to himself the vain and self-satisfying appellation of "lord of the creation," were to remember that the glorious sun, and the planets which revolve around it, form but one particular division, class, or system in the universe,—that the earth is but an humble member of that system, and that he, man himself, is but a moving particle on the surface of this earth,—he may well be expected to give utterance to the sentiments of David, and to wonder how the Great Deity can regard with parental care so humble a member of so magnificent a whole.

But this feeling, as Addison has beautifully shown, arises from the narrow powers of our own minds. We know that our perceptive faculties soon reach a boundary beyond which we cannot pass: we study the laws of Optics, but we know not the nature of Light:—we feel that we live and think, but we know not what constitutes life and thought. When, therefore, we judge of the Great Creator, by our own standard, we are lost in wonder at the vastness and at the minuteness, as also at the countless number of the objects which are under the Divine protection. But when we consider God as an Omnipresent and Omniscient Being, we then admit, indeed, that nothing is too vast, nothing too minute, nothing too numerous, for his notice; that He who could create and arrange the whole, can also watch over and preserve the minutest parts of that whole. Our notions of great and small are derived from our own imperfect experience, and strikingly show the limited scope of our minds. The distance of the sun from the earth is a quantity so immense, as almost to perplex the mind which reflects on it; and yet that distance is small, compared with the distance of the fixed stars:—again, the minuteness of the nerves and smaller blood-vessels of the human body, is such as to require the microscope to aid us in an examination of their structure, and yet there are other entire animals, endowed with life and powers of motion, which are so minute that the eye cannot perceive them. The words *great* and *small*, then, are for man's use; to the Almighty nothing is great, nothing is small; the revolving planet, and the animalcule whose world is a drop of water, being equally objects of his ever-active care. This divinely-sustaining power of Him, in whom "we live, and move, and have our being," is so obvious, that we may exclaim with the poet Thomson—

Were every falt'ring tongue of man,
Almighty Father! silent in thy praise,
Thy Works themselves would raise a general voice,
E'en in the depth of solitary woods
By human foot untrod;—proclaim thy power,
And to the choir celestial Thee resound,
Th' eternal cause, support, and end, of all!

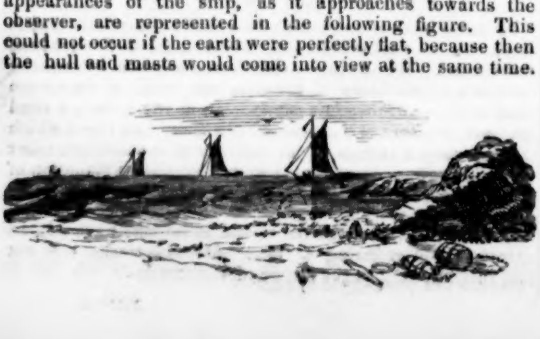
Nothing is more calculated to elevate the mind, and to display to us the wonders of Creation, than the study of Astronomy. We propose, therefore, to place before our readers a popular view of the elements, which serve for the basis of the astronomer's study. In doing this, we need not have recourse to the mathematical reasonings on which the various statements of the astronomer are founded; but we shall confine ourselves to such a simple explanation of the Mechanism of the Heavens as may pave the way for the study of a more systematic treatise. We trust, therefore, that both those who have, and those who have not, an opportunity of referring to more elaborate works, will not find the following pages devoid of instruction.

## GENERAL APPEARANCE OF THE HEAVENS.

LET us suppose a man to be totally ignorant of Astronomy, and to turn his attention from events occurring upon earth, to those which are presented by the heavens. He sees a brilliant and glowing body, the Sun, rise in the east, at from four to eight o'clock in the morning, (according to the season of the year.) This body gradually attains a considerable altitude in the heavens, and continues to rise until noon;—it then gradually descends, and in its descent, bends towards the west, where it sinks, (apparently below the earth,) some time between four and eight o'clock in the afternoon. The spectator now loses sight of the glorious orb, which does not again become visible for several hours; and when it does again appear, it is not at the point where it escaped from view, but at the opposite side of the heavens, namely, at the point where it first appeared on the preceding day. On watching the progress of the sun, he finds that the path, before noticed, is again travelled over by the luminary, which becomes lost to his view, as before, in the west. A third and a fourth day the same phenomenon occurs; and the question naturally suggests itself to the observer's mind, "Is it the same cheering and dazzling visiter which I see day after day, or are they different bodies, resembling one another, and following one after another?" Were he to confine his attention to the occurrences of only a few days, he would, perhaps, think the latter supposition to be correct, viz., that they were different bodies which thus appeared to him day after day. But if he were to continue his observations for weeks, months, years, or the greater part of his life, and to find that the daily appearance of such a body still continued, he could hardly fail to conclude that it was the same body which thus so frequently attracted his attention and admiration. "But how?" (he might say,) "do I not see this ruddy disc of light dip into the ground in the west, and appear to me again in the east on the following morning: what becomes of it in the meanwhile?" To answer this question, or to obtain the means of answering it, he would, perhaps, trace more particularly the path which the sun followed from morning to evening, which he would find to be a semicircle, or a curve not differing much from it. If, likewise, he were to take note of the time occupied in these occurrences, he would soon find the time that the sun is above the surface of the earth to be, on an average, equal to the time that it is invisible.

From these two facts, it would be by no means unreasonable to arrive at the conclusion, that the sun moves in a circle; and that, while he is invisible to us, he is passing round the earth, in a direction from west to east, at which latter point he arrives at the moment that the observer sees him rise in the morning.

Here a difficulty arises, which it may well be supposed, would perplex the uninitiated observer. What can be meant by going round the earth, if the earth be, as it seems to our eyes, a flat and extended surface of ground, or water, which seems to touch the sky at the farthest points which the eye can reach:—how then can the sun pass round this? There can scarcely be a more reasonable question, so long as we judge merely by what meets the eye; but, if we extend our observations to certain appearances on the ocean, we begin to see proof that the surface of the water is not quite flat. On land, we have not the means of making a similar observation, because of the intervention of mountains and valleys. The proof that the surface of water is not quite flat, is derived from the following circumstance. If we are at sea, on a clear day, and watch the approach of a vessel from a distance, we find that the masts are visible sooner than the hull: we first see the top of the masts; then the whole height of the masts gradually comes into view; and finally, we see the hull. These different appearances of the ship, as it approaches towards the observer, are represented in the following figure. This could not occur if the earth were perfectly flat, because then the hull and masts would come into view at the same time.



It matters not what part of the world be chosen as the place of experiment; the result is almost exactly the same every where, and the amount of the bending of the surface of the ocean may be illustrated thus:—If we had a piece of string four miles long, and were to apply both ends to the surface of still water, and could possibly draw the string into a perfectly straight line, the middle of the string would be about sixteen inches below the surface of the water; thus showing that the water is not quite flat.

Thus might be supposed to arise the first conjecture that the earth is round, like a ball; a fact which was clearly proved by Captain Cook, who was the first to perform a voyage completely round the earth, about the year 1769. He left a given spot, and arrived again at that spot by an opposite course. There is an abundance of proof, derived from other sources, that the earth is a globe; but those will open upon us more plainly, as we advance.

We have hitherto endeavoured to trace what would probably be the feelings and opinions of one who, without previous instruction in Astronomy, should note the appearances presented by the sun. But that golden orb is not seen to be a solitary inhabitant of the sky: another luminous body about as large in apparent size as the sun, would soon attract the notice of the gazer. He would see it rise in the east, soar aloft, and then sink in the west. After the lapse of a few hours it would again appear in the east, attain a height from which

............With a boundless tide
Of silver radiance, trembling round the world,

it would again descend, to sink as before in the west. The train of reasoning which would lead the observer to conclude that the sun revolved round the earth, would lead him to a similar conclusion regarding the moon. But here the resemblance terminates. The sun always presents a perfect circle to the eye of the observer day after day, and month after month; but a few evenings suffice to show that such is not the case with the moon: at one time a crescent only is seen, whose hollow side is towards the left of the observer; at another time the hollow side is towards the right: the crescent sometimes enlarges to a perfect circle; and at others it contracts from a circle to a crescent. If, then, the moon be a ball or globular body, shedding light upon the earth, there is great difficulty in conceiving what can occasion the change in its apparent shape; but, if we were to consider the moon to be an opaque or non-luminous body, we should find the means of explaining the change in its apparent figure, by supposing that the sun shines upon the moon, and that it is only by the reflection of the sun's light from the moon that the moon becomes visible to us. If we place a large round ball on a table, in a place where the sun is shining, we shall see the ball more or less illuminated, according to our position with regard to the ball and the sun; in one position, the ball will appear to be equally divided by a boundary line, into two semicircles, one illuminated and the other in the shade: in another position, the illuminated portion will be only a crescent, all the rest being shaded: from another point again it will all appear illuminated, except a small crescent of shade. If the observer watch the relative positions of the sun and moon, he will see that the shape of the bright part of the moon depends on its relative position in respect of the sun; just as the bright portion of the illuminated ball depended on the position in which he viewed it.

We should in this way find the means of accounting for the change in the shape of the moon. We shall, by and bye, show that these suppositions are really true. But another point would attract the notice of the observer, independently of the change in apparent form. If the two brilliant bodies, the sun and moon, were observed to be near each other on a certain day when the latter appeared as a thin crescent to the left of the sun, they would be seen the next day further removed, and on the following day, at a still greater distance from each other: if, therefore, the motion of the moon round the earth be admitted, it is necessary to suppose that motion to be slower than the sun's motion round the earth.

But in addition to the glowing light of the sun and moon, a glittering assemblage of smaller bodies meets the eye of the observer: a crowd of little spangles adorns the sky when the sun has left it, and softens the dreary darkness which results from his absence. These stars are seen to resemble the sun and moon in the circumstance of rising in or near the east, attaining a certain altitude, and setting in the west; from which circumstance the observer infers

that the stars, like the sun and moon, revolve round the earth. But, by a careful attention to different stars, he would find that the same remark does not apply to all. Those which rise exactly in the east, set exactly in the west; those which rise to the south of east, set south of west; and many which rise somewhat north of east, set somewhat north of west; but in looking northward he sees stars which appear neither to rise nor to set, but which perform a complete circle round a particular point of the heavens. For example,—there are seven stars, which, to most persons who pay any attention to the appearance of the heavens, are known under the name of the Great Bear. These stars never rise or set to an inhabitant of London. If they become invisible, it is either because clouds obscure them, or the superior brilliancy of the sun drowns their comparatively feeble light. The same may be said of five conspicuous stars known by the name of Cassiopeia's Chair.

If we watch the progress of these stars, and others in their vicinity, we shall find that they describe a circle round a star called the Pole-star. The position of this star we shall find to be nearly this: if we suppose the distance from the north point of our horizon (which is the line in which the surface of the earth appears to touch the sky) to the zenith (which is the point immediately over our heads) to be divided into five equal parts, then at about the height of three of those parts from the earth, will be seen the Pole-star.

All this would seem to show to an observer, that the Pole-star is the end of an axis round which all the stars revolve, and that the reason why we cannot see the whole circular path of any stars except of those in the vicinity of the Pole-star, is, that they pass round under the earth during a part of their journey, and are therefore concealed from our view. Those stars which are further removed from the Pole-star describe a larger circle than those which are nearer, while the Pole-star is almost stationary. This is exactly what takes place when we see a wheel turn round; the axle remains in one spot, but any particular point on the outer edge of the wheel describes a larger circle than that which is described by any point between the axle and the circumference.

If we consider the Pole-star to form one end of the axle or axis round which the stars revolve, then it is obvious that there must be an opposite end of the same axis, in the contrary direction. If then we turn towards the south, with the expectation of seeing such a point, we shall find that it will not be realized; for none of the stars in that quarter are seen to describe circles; for they all rise and set. Still, however, the semicircles or portions of semicircles, commonly called arcs, which they describe, appear to have a common centre, which is some distance below the horizon; and this centre may be considered as the southern end of the axis before spoken of.

If we suppose the observer to have arrived at this amount of information respecting the stars, he will be prepared to notice the uniformity of the positions of the stars with respect to one another. The Great Bear, for instance, whether it be under or over the Pole-star, or at the right or the left of it, will always have its seven principal stars at the same relative distances from each other. The changes which take place in the distance of the sun from the moon, would lead to the opinion that these revolve round the earth in unequal times; and by similar reasoning, the constant maintenance of the same distance between any two stars, would seem to imply that the stars revolve in equal times.

The seeming myriads of stars which present themselves to the notice of the observer all appear to follow this rule, of remaining at the same relative distances from one another, with very few exceptions. These exceptions, are, indeed, so few, that a constant watching of the same part of the heavens for a considerable period, would be necessary to determine that a star had actually changed its place relatively to other stars. There have, however, been discovered at different times ten stars, more or less brilliant, which change their relative distances from one another, and from other stars. These we know by the name of Planets; and by a careful attention to their movements, it is seen that each one travels in a curved path among the other stars, and returns again nearly to the point from whence it set out.

At intervals, again, star-like bodies of another order present themselves, whose progress among the other stars is more rapid than that of the planets; and which at a period more or less brief, vanish altogether from the view of the observer, and do not return till after a long absence. To such bodies we give the name of Comets.

Such then are the equally sublime and facinating appearances which present themselves to the eye of an observer, when that eye is directed towards the heavens. That the invigorating and fructifying warmth and light shed by the sun,—the serene, quiet light of the moon,—and the diamond-like glittering of the stars,—should invite men to a study of the laws which, under their Divine Creator, govern the motions of such exquisite globes of light, is what we are not only prepared to expect, but fancy that we should feel disappointment in finding it otherwise. Man is not, by nature, the cold heartless being who can let such beauties pass unheeded; and if he approach the study with the humility which true self-knowledge is calculated to engender, he becomes more and more able to appreciate the surpassing grandeur and power of the great Being who made and who rules all. Well, indeed, may we direct our attention to the phenomena which we have briefly described, and to which Milton so exquisitely alludes in the following lines:—

First in his East the glorious lamp was seen,
Regent of day, and all th' horizon round
Invested with bright rays, jocund to run
His longitude through Heaven's high road; the gray
Dawn, and the Pleiades * before him danced,
Shedding sweet influence: less bright the moon,
But opposite in levell'd West was set
His mirror, with full face borrowing her light
From him; for other light she needed none
In that aspect, and still that distance keeps
Till night; then in the East her turn she shines,
Revolved on Heaven's great axle, and her reign
With thousand lesser lights dividual holds,
With thousand thousand stars, that then appear'd
Spangling the hemisphere: then first adorn'd
With their bright luminaries that set and rose,
Glad evening and glad morn crown'd the fourth day.

*Par. Lost*, b. vii.

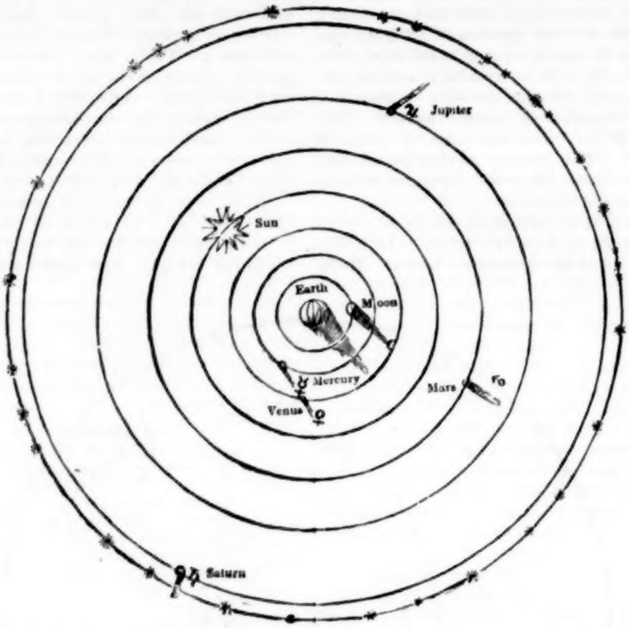
### THEORIES TO EXPLAIN THE MOTIONS OF THE HEAVENLY BODIES.

In very early ages, before Europe occupied a page in the history of nations, the phenomena of the heavens were studied with great attention by several nations of the East. The Chaldeans, the Indians, the Chinese, and the Egyptians, have all left evidences of the industry and ingenuity with which their observations were conducted. They constructed observatories,—invented instruments for observing and measuring with accuracy,—separated the stars into different groups, called Constellations, for the facility of finding any particular star,—gave particular names to most of the moving stars or planets, and noted the period which each took to move through its apparent path in the heavens; and, in many other ways, the ancients helped to lay the foundation of that mass of astronomical knowledge which the men of later ages have brought to more maturity.

Various opinions were formed respecting the motions of the sun, moon, and stars of all kinds, both with reference to one another, and also to the earth; but the first theory which had attained a name and an importance in the early ages of the world, was that of Ptolemy, a distinguished Egyptian astronomer, who lived about one hundred and thirty years after the birth of Christ. He conceived that the various bodies which had been distinguished by the appellation of "the heavenly host," were disposed in the order represented in the annexed diagram.

He supposed, according to the popular opinion, that the Earth was fixed as the centre of the universe, and that the Sun, Moon, Planets, and Stars, revolved round it in the following order; namely—the Moon, Mercury, Venus, Sun, Mars, Jupiter, and Saturn; the Moon being the nearest, and so on; exterior to all of which, he supposed that a great concave sphere in which all the stars were fixed, kept on revolving round the earth. From the early history of Astronomy, we learn that before the time of Ptolemy, it had been conjectured by some, that the earth passed round the sun, and not the sun round the earth; but the difficulty of believing a statement so contrary to appearances and to the evidence of one's physical senses, led to the rejection of this opinion; and although it was afterwards found to be

* Seven small stars clustered together in the constellation Taurus. These stars rise with the sun about the time of Spring, and our poet, in this passage, intimates the old and common opinion that the Creation took place in the Spring.




THE PTOLEMAIC SYSTEM.

correct, yet nearly two thousand years elapsed before such a theory was generally admitted by philosophers.

After Ptolemy had promulgated the theory which bears his name, he found that there were certain difficulties which followed from the adoption of it. He conceived that the seven bodies mentioned before which revolved round the earth, moved in the same general direction from West to East. But on watching the progress of some of the planets, he found that they did not appear to travel uniformly round the earth, but seemed to have, at certain times, a retrograde or opposite motion, with reference to the other planets; while at other times they seemed to be stationary. To account for this, he was obliged to suppose that those planets did not revolve in a perfect circle round the earth, but that they described a peculiar path called an epicycloid, of the nature of which some idea may be formed from the following illustration:—if we had a large coach wheel, and by any contrivance could make a smaller wheel roll round the outside of it, at its circumference, then, any particular point on the small wheel would describe that curve which is called an epicycloid: the axle of the small wheel would describe a perfect circle, but it is easy to see that any point on the edge would not describe a circle. Ptolemy was obliged to multiply these epicycloids to a most perplexing extent, in order to account for the various appearances of the planets. It is to this circumstance that Milton alluded, when he spoke of the shifts and difficulties which beset the progress of those who build their opinions on a wrong foundation:—

When they come to model Heaven
And calculate the stars, how they will wield
The mighty frame; how build, unbuild, contrive,
To save appearances; how gird the sphere
With centric and eccentric scribbled o'er,
Cycle and epicycle, orb in orb.——*Par. Lost*, b. viii.

There is nothing which more beautifully shows the power and force of truth, than the embarrassments which retard the progress of those who do not take truth for their guide. In religion, in morals, in science, he whose steps are guided by the light of truth, can arrive, by a short and pleasant path, at results which others can scarcely obtain by a complex and wearying track. Thus Ptolemy was forced to assume the existence of much unwieldly machinery in the scheme of the heavens, in order to account for those motions which are most simple and beautiful; this was because he placed (in his own imagination,) the earth in the midst of the heavenly bodies, all of which were made to revolve round it.

Great as were the difficulties which attended the adoption of the Ptolemaic system, it yet retained its ground, with some slight modifications, until the time of Nicholas Copernicus, an eminent astronomer, who was born at Thorn, in Polish Prussia, in 1473. This distinguished individual perceived the unreasonable results which follow from the theory of Ptolemy. That all the planets, the sun, the moon, and all the stars and comets, should revolve round the earth, seemed to him much more unnatural and complex than that the earth should revolve on its own axis, and move in an orbit round the sun. All the appearances of the heavenly bodies can be explained with much greater ease and simplicity by the latter supposition than by the former; and Copernicus was thus led, after the study of forty years, to the adoption of a theory which had been advocated by Pythagoras and Thales of Greece, five or six hundred years before the time of Ptolemy.

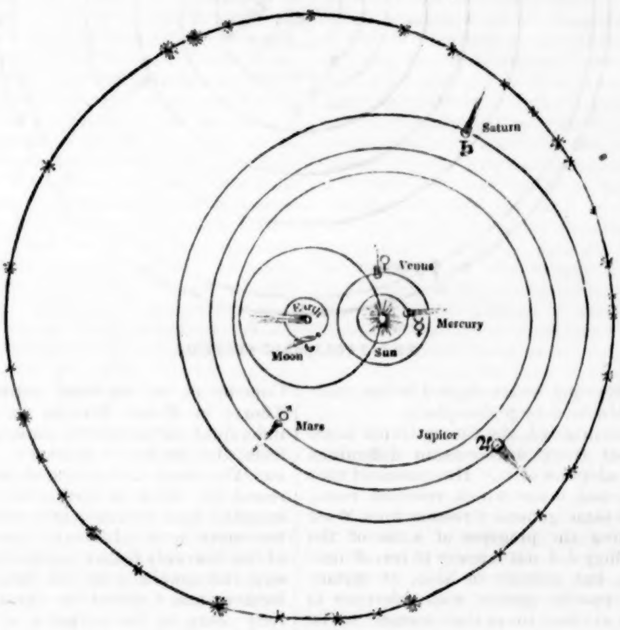
The frontispiece to this number is a representation of the solar system, according to the theory of Copernicus. In this system, the sun, the glorious source of light and heat to us, is placed in the centre. Round him the planets revolve in the following order:—Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Since the time of Copernicus, five more planets have been discovered, namely, Uranus, Pallas, Vesta, Juno, and Ceres. In order to account for the phenomena presented by the moon, Copernicus assumed, (what has since been confirmed,) that the moon has a two-fold motion,—round the earth and round the sun: a small circle, therefore, surrounds the earth, which circle represents the path of the moon round the earth, while the earth and the accompanying moon together revolve round the sun. The frontispiece of course represents the Copernican system with the addition of the five planets since discovered. The circles represent the orbits of the several planets; that is, the paths in which they travel in their progress round the sun. The distances of these circles from the centre at which the sun is placed, could not conveniently be in the same proportion one to another, as the real distance of the planets is respectively from the sun, because the innermost orbits would be too small to be conveniently seen. The real proportions, however, which exist between the distances of the planets from the sun, admit of being easily understood. For instance, the earth, (as we shall hereafter explain more fully) is about ninety-five millions of miles from the sun. If now we call that distance 1, the distances of the other ten planets from the sun, will be represented by the following numbers, with sufficient nearness for our present purpose.

| | | | |
|---|---|---|---|
| Mercury | $\frac{2}{5}$ | Ceres, Pallas | $2\frac{3}{4}$ |
| Venus | $\frac{3}{4}$ | Jupiter | $5\frac{1}{2}$ |
| Earth | 1 | Saturn | $9\frac{1}{2}$ |
| Mars | $1\frac{1}{2}$ | Uranus | $19\frac{1}{5}$ |
| Vesta | $2\frac{1}{3}$ | | |
| Juno | $2\frac{2}{3}$ | | |

There was an astronomer of very great skill, who lived about the same time as Copernicus, who thought that a mean might be struck between the theories of Ptolemy and Copernicus, by which the favourite idea of a celestial revolution round the earth might still be retained, and so concession might be made both to the growing authority of science, and to the persuasion of men's senses. This astronomer was Tycho Brahé, who was born in 1546, at Knudstrup, in Denmark. The system advocated by him, and which is named from the inventor the Tychonic system, is represented in the annexed diagram.

In this system, which was published about the year 1586, the Sun is considered as a centre, round which five of the planets revolve; namely, Mercury, Venus, Mars, Jupiter and Saturn; while at the same time, the Sun himself, with all those planets, revolves round the Earth. It certainly appears strange that a man of such eminent abilities as Tycho was, should have preferred this ponderous arrangement to the more simple theory advocated by Copernicus. After the death of Tycho, his theory gradually sank in the estimation of philosophers, who found, in the arrangement advocated by Copernicus, the means of explaining celestial phenomena by less complex reasonings than by the theories either of Ptolemy or of Tycho Brahé.

Here, then, we arrive at an important part of our subject; that there are, as we shall hereafter show more clearly, immense bodies revolving in orbits which measure millions of miles across. The appearances presented to the eye




THE TYCHONIC SYSTEM.

lead to an opinion that these bodies revolve round the earth; but a further inquiry into the accompanying circumstances, have led men universally, at the present day, to conclude that the earth and the other planets revolve round the sun.

What then can keep these splendid bodies in motion? How did they first begin to move? And why do they revolve round the sun instead of moving in a straight line? These questions naturally occur to our minds, for our humble faculties can give us but a faint idea of the powers necessary to keep such immense masses in motion. If we see a carriage passing with great rapidity along a railway, we can account for its motion, by tracing the action of steam-pressure upon a piston; which, by connecting machinery, makes the axles of the wheels revolve, and thus sets the whole vehicle in motion. If we see a carriage passing along the street, we can assign a cause for its motion, by the muscular efforts of the horse which is attached to it. If a ball be shot from a cannon, its flight is so rapid as to render it invisible to us, but we can account for its motion by considering that a quantity of gunpowder, small in bulk, suddenly enlarges to about two thousand times its former dimensions, by being converted into gas, when heat is applied; and that the endeavour to obtain two thousand times as much room as it before occupied, acts with such pressure against the ball as to force it out with fearful velocity. All this we can understand, because we can trace the progress of the occurrences step by step. But when we turn to the heavens, we are lost in wonder! Our means of judging admit of no such details of comparison as those which before assisted us; and we are brought to the conclusion that the Almighty, for his own wise purposes, impressed upon the heavenly bodies those motions which we know they possess,—which we can calculate and measure,—but the origin of which we can here never know.

But ought this circumstance to prevent us from studying the nature and extent of the motions impressed upon these glorious bodies? Is it presumptuous in us to endeavour to become acquainted with the laws which, once known, will give us additional proofs of the wisdom and power of the Divine architect of the heavens? Assuredly not! The origin of those movements we know not, but the study of the nature and direction of them is a noble and fitting employment for the human mind.

In the century following the age of Copernicus and Tycho Brahé, there sprang up a genius, who was destined to add more to the amount of human knowledge in this path than any one, perhaps, who had previously existed. This was Sir Isaac Newton, who was born in 1642, at Woolsthorpe, in Lincolnshire. This distinguished man displayed from boyhood an ardent love for the study of the natural phenomena around him. When a child, he made clepsydras, or clocks which told the hour by the descent of water through an orifice at the bottom of a vessel. He also constructed a windmill, which was worked, in part, by a mouse placed inside. As he grew towards manhood, his soaring mind directed itself to the sublime phenomena presented by the heavens, and to the nature and composition of light. That part of his career which more particularly concerns us at present, we will now consider.

When Newton was about twenty-three years of age, he was forced to leave Cambridge where he had been residing, on account of the appearance of the plague at that town. He retired to Woolsthorpe, where, sitting one day in his garden, he saw an apple fall from a tree at his feet. The falling of an apple might have been noticed often enough; but Newton's searching mind directed itself to this inquiry: "Why does the apple fall, when it is loosened from the tree?" Some may laugh at such a question,—some have laughed at it,—and yet the only answer which the laughers

could give, would be, "Because it is the nature of things to fall, when unsupported." This vague explanation did not satisfy the sagacious Newton. He set himself to consider the nature of the occurrence which had attracted his notice, and of others similar to it, and he finished by framing that train of opinions which, under the name of the Theory of Gravitation, laid the foundation of all correct knowledge of the motions of the heavenly bodies, and which is now received by all who deserve the name of philosophers.

> All intellectual eye, our solar round
> First gazing through, he by the blended power
> Of gravitation and projection saw
> The whole in silent harmony revolve.——THOMSON.

We shall here find it convenient to consider the nature of this force of gravitation, and will endeavour to do so in the simplest way possible. Every particle of matter in the creation has a tendency to attract, or draw towards itself, every other particle, however distant it may be. We know not what this attraction is; we can therefore only judge of it by its effects. This attraction is of different degrees of force according to the size or density of the attracting body. A small loadstone or magnet will take up a little key, whereas a larger magnet will take up a larger key: so it is with attraction; a lump of lead weighing one pound only, attracts a distant body with half the force which is exerted by another piece of lead weighing two pounds. Again, the force of this invisible agency is subject to variation with respect to the distance between the attracting and attracted bodies. If a mass of lead be the attracting body, and two equal-sized bodies be at some distance from it, the one which is the nearer of the two will be attracted with greater force than that which is further removed. The diminution of attractive power from increase of distance is much more rapid than from the lessening of the size of the attracting body. For instance, if any mass of matter attract another mass with such force as to make it move through twenty feet in a second of time; then, if the first mass be removed to double its former distance, the strength of the attraction will be so much weakened, that the second body will move only five feet in a second, or with one-fourth of its former rapidity.

These simple principles, when applied to such immense bodies as the planets, produce results of a gigantic kind. It may be asked, "If a pound of lead will attract a piece of cork more strongly at the distance of one than of two feet, how is it that we cannot see the proofs of such a fact in practice?" The reason is, that the earth itself forms such an enormous mass of matter that it completely neutralizes the effects of the comparatively small bodies at its surface. In strict truth, if an apple be suspended from the branch of a tree, it tends to attract the earth upwards to meet it; but the attraction of the earth for the apple is so incalculably more powerful, that the moment the apple is loosened from the tree, the earth draws it down to meet it, and that is what occurs when we say that the apple falls. Suppose that, instead of an apple, a mass of lead weighing a thousand pounds, were for a moment suspended in the air; the lead would tend to attract the earth upwards towards itself with much greater force than the apple had done; but still the earth's attraction would so completely overpower the lead, that it would be drawn down to the earth; while the latter would rise to meet it by a quantity, wholly inappreciable by mortal sense, though not by computation.

But let us now suppose a body placed in the universe, equal in size to the earth, but at some distance from it. Here we perceive that there is no reason why the earth should attract the other body more strongly than the latter attracts the earth; accordingly, if they were both free to move, they would naturally approach towards each other, each one moving through half the distance which separated them. If, therefore, we were to suppose that the universe contained many such bodies, each as large as the earth, each one would attract all the others, with a force varying only as the several distances varied. But if one body were very much larger than any of the others, it would attract each of the others more powerfully than itself could be attracted; and would not, therefore, have to move through so great a distance to meet any of the other bodies, as they would have to move through, in order to meet it.

All this admits of being impressed upon the mind with tolerable clearness, so long as we consider the bodies to be in the first instance stationary, and then receiving an impulse. But how can we explain the curved path which each of the heavenly bodies describes in its progress through space; and why do not all the planets get close together by virtue of the attraction which draws them one to another? These questions we cannot answer without a previous attention to other particulars, which we must shortly explain.

If we stand at the top of a high tower, and throw a stone forward to the ground, we shall find that the stone will not proceed on in a straight line, but that it will soon assume a bending path and approach towards the earth. The direction in which this bending occurs, is such as to bring the stone to the earth in a more perpendicular direction than it had when it set out. Now the reason why the stone is thus forced to change the direction in which it first began to move, is, because the earth attracts it and hastens its descent. If we suppose it possible that a hole could be bored through the earth from side to side, we should find the mass of matter would be more accumulated in the direction which passes through the centre of the earth than in any other direction; and as bodies attract other bodies in proportion to their mass of matter, we see reason to believe that a falling stone is attracted more powerfully towards the central direction of the earth, than towards any other part. When, therefore, the stone has left the hand, it gradually tends to a direction perpendicular to the surface of the earth, or it gets into a direction which, if continued, would lead to the centre of the earth.

Now if there were no such force as gravitation, the stone would proceed in the same straight line in which it was first propelled. If it were thrown upward from the surface of the earth, it would continue to travel upwards, without ever again descending to the earth. Here we should remember that there is in nature no such thing as *up* and *down*; but that *up* means simply a departure from the centre of the earth, *down* an approaching towards that centre.

We all know with what amazing velocity a cannon-ball moves, after it has left the mouth of the cannon; yet it soon begins to decline towards the earth, whether it be originally shot from the cannon in a horizontal or in an upward direction. But still the curvature of its path towards the earth is much less rapid than in the case of the stone, because the latter moved so much more slowly. The mortar in St. James's Park can propel a bomb to a distance of about four miles, before it will fall to the earth; whereas a stone thrown by a very powerful arm would certainly fall to the ground within a few hundred yards. Suppose, now, that it were possible to increase to an indefinite extent the velocity with which a cannon-ball would move; say that it should travel ten or twenty miles before it touched the ground; a greater velocity would carry it one hundred miles before it fell: and we may go on in the same train to any extent we please, always bearin mind that, the quicker the body moves, the greater distance will it travel before it falls to the ground. Now, if we assume such a velocity that the ball would travel twenty-five thousand miles before it fell to the earth, we shall arrive at a very curious result. The diameter of the earth is almost eight thousand miles, which gives, for the circumference, about twenty-five thousand miles. The ball would, therefore, have gone completely round the earth before it fell to the ground. If the velocity were still greater it would not reach the ground at the completion of this circuit, but would go on to describe part of another revolution round the earth. When this condition is once attained, the ball might, by a due increase of the projectile force, continue to revolve for ever about the earth, and we should thus have a cast-iron satellite moving around us.

Let not the reader smile at the absurdity of supposing a cannon-ball to travel twenty-five thousand miles; for it will lead us to important results. If we suppose that the sun were stationary in the universe, and that a body very much smaller than the sun were to be projected with immense velocity in a direction at right angles to a line joining the sun and the other body, then the latter (which would proceed in a straight line if the sun were not present) is drawn by the sun into a curved path, the concave or hollow side of which is always towards the sun. If the velocity with which this body were propelled were below a certain limit, it would move in a spiral which would gradually end at the sun himself, to which, therefore, the body would fall: if the velocity were beyond a certain limit, the body would describe a spiral round the sun, but gradually receding from it, and the body would continue through infinite ages to recede farther and farther from the sun: but if a certain velocity, of a corresponding ratio with the attractive power of the sun, were imparted to this body in the first instance,

it would move constantly round the sun, arriving at every revolution at the point from whence it started.

We are now in a condition to explain in some degree how we are to regard the motions of the planets round the sun. When the Almighty had created the various bodies which compose the universe, he exercised his infinite power and wisdom by imparting to them various velocities of motion. The sun being made very much larger than all the planets put together, exerted a more powerful attraction on them than they could exert on him; consequently, the planets were drawn towards the sun out of their original paths, and made to revolve round the larger body. But how shall we sufficiently admire the exquisite skill with which the various velocities were adapted to the size of the various bodies! What parallel can we find in the poor and imperfect works of man, to that surpassing power of adjustment by which the velocities of the planets are regulated! The earth moves some hundreds of thousands of miles in a single day; and yet, if her velocity were to deviate by a small fraction, either more or less, the earth would, in the first case, gradually recede from the sun, and never again approach near him; and in the second case, it would approach to, and fall upon, the sun. It is when such results as these are obtained, that science enables us to appreciate the striking truth, that man's efforts even in his proudest moments, are but poor and humble attempts to follow after, or to imitate, that which the Great Being performs with such boundless perfection. We applaud, and we give rewards to the man, who can make a chronometer which will be accurate within a few seconds in the year; and well may we do so, for it is a signal instance of human industry and ingenuity to produce such an instrument. Yet a mere fraction of such an error in the movements of the bodies composing the solar system, would be fatal to its stability. Truly wonderful, indeed, is it, that the eleven planets should revolve round the sun in periods differing greatly one from another, and at such various distances from him; and yet, that each one should have a velocity so exquisitely adjusted to its size and position as to bring it precisely round to the same point after every entire revolution round the sun. The sun, then, the golden magnet which thus draws all the other planets towards itself, is surrounded with whirling worlds, which borrow their light from him and share it with one another. Well might the poet of the seasons exclaim—

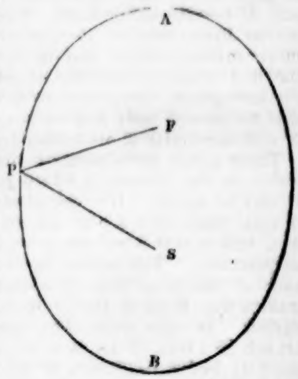
> .................... Thou, O sun!
> Soul of surrounding worlds! in whom best seen
> Shines out thy Maker! May I sing of thee?
> 'Tis by thy secret, strong attractive force,
> As with a chain indissoluble bound,
> Thy system rolls entire: from the far bourne
> Of utmost* Saturn, wheeling wide his round
> Of thirty years, to Mercury, whose disk
> Can scarce be caught by philosophic eye,
> Lost in the near effulgence of thy blaze.

### FORM OF THE ORBITS OF THE PLANETS.

OUR remarks hitherto have been so expressed as to lead to the conclusion that the planets move in perfect circles round the sun at all times, and under all circumstances. Such, however, is not strictly the case. The paths which they describe are oval or elliptical. Most persons know the form which is meant by the term oval. If we hold an egg in the hand, and look at its outline, it will give a near approach to this form: and, indeed, the word *oval* is derived from *ovum*, the Latin for *an egg*. Such, then, is the form of the paths in which the planets move. Now we may inquire whether the sun is exactly in the middle of this oval, or near either end of it. To this it must be answered that the sun is not precisely in the middle, but that he is a little nearer to one side than the other. It will be useful to give an idea of the position which the sun occupies. Suppose A B represent the orbit or path in which a planet (such as the earth) moves round the sun. (We have made this a larger oval in proportion than the earth's orbit really is, in order that our meaning may be more conspicuous.) There are two points F and S (called *foci*, plural of the Latin word *focus*, signifying *a fire-place*), which have peculiar properties. If we stick a pin in each of the points F and S, and fasten the two ends of a bit of thread to them, (taking care that the thread is just long enough to reach to any one part of the circumference, as at P,) we shall find that we shall be able to make the thread exactly touch every other part of the oval, by stretching it out; but that we cannot make it extend beyond the oval in any direction.

Now it is in one of such points F S that the sun is situated, in the earth's orbit. The oval, if we could possibly see it at once with the eye, would scarcely appear to us to deviate from a circle: it being rather a round, not a long oval. We here speak only of the earth's orbit, but the same remark applies to the orbits of all the planets, which orbits are all more or less oval. We use the term *oval* in preference to the term elliptical, because it is more familiarly known; the meaning of each is, however, the same.

We may now be asked, whether the planets move equably in every part of their orbits,—that is, If a planet move at the rate of so many miles in an hour at one part of its orbit, will it move with the same velocity at another part? This question, on account of the oval form of the paths in which the planets move, must be answered in the negative. They do not move equably in different points of their orbits. Suppose that in the following figure, the point S were like the axle of a wheel, and that twelve equidistant spokes, or radii, reached from it to the boundary of the oval, then the earth, in passing by the end of each spoke during her revolution, would not pass from one to another in exactly equal times, but would take a longer time to pass from spoke to spoke at one part of her revolution than at another. But now let us suppose, that the *time* which the earth takes to revolve round the sun be divided into twelve equal parts, and that we draw a spoke from the axle, or the point S, to the boundaries between all the twelve spaces respectively passed over by the earth in those equal times; then it will be found that the open space between any two adjoining spokes, measures exactly the same number of square miles at every part of the orbit. The spokes towards the end A will be closer together than those towards B, but they will at the same time be longer, so that the excess of length precisely compensates for the deficiency in width. Here is another instance of the admirable adjustment which is observable in the motions of the heavenly bodies. The orbits of the planets are all oval, and differing in the form of the oval; yet the law which we have just stated is found to be constant. The more the orbit approaches to what we may term a long oval, the greater is the difference between the lengths of the spokes towards the two ends. Yet in every case, a disagreement in length is made up by a reverse disagreement in the openings between them, so that these areas or openings are all equal. We have been anxious to avoid every appearance of scientific difficulty in these details; but we will just mention that those who may be able to consult larger works on Astronomy, will find this law thus expressed; that "a planet always describes equal areas in equal times."




Those fleeting and transient visiters, comets, are too seldom in sight to afford the means of making such correct observations of the nature of their orbits, as have been made with respect to the planets. We shall, by-and-by, have to speak individually of several comets, which have appeared at various times, but we now merely refer to their motion generally. It is now believed, from the best observations which have been made, that the comets move in exceedingly long oval orbits, by which means they are at one time very near to the sun, and at other times at an immense distance from him; still, however, the same general resemblance to the orbits of planets is to be noted, and, in addition, that the elongation of the form of the cometary orbit is frequently excessive.

We shall hereafter have to show, that the four largest of the planets have moons, or satellites, revolving round them, of which our moon, the earth's satellite, is the one which attracts a larger share of our attention than any of the others. Now it is interesting to observe, that the moon of itself describes an oval orbit round the earth, in a similar manner as the earth does round the sun. But here a singular effect results:—if the earth were stationary, the moon's orbit would be found, as in the case of the planets,

* Thomson had written this before the year 1730; and the planet Uranus was not discovered until 1781.

to be an oval with respect to the earth; as, however, the earth revolves round the sun, and, of course, carries the moon with it, the real path of the latter becomes a very singular and complicated curve,—it is a zig-zag circle round the sun, with several indentations and as many protuberances.

Thus then do we form some general idea of the manner in which the planets are situated, with respect to one another and to the sun. It will be useful to recapitulate a few points before we proceed further.

We have seen that there is a glorious luminary, the Sun, in the centre of a moving system; that there are eleven planets revolving round him in the following order, beginning from the nearest,—Mercury, Venus, Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus; that these planets describe paths which are not quite circular but oval, and that the sun is in one focus of the ellipse or oval. The motions of the planets we have likewise found are not uniform, but that their velocities vary according to their distances from the sun. These general details will qualify us to enter upon the consideration of all the planets individually, their dimensions, distances from the sun, velocities of motion, influence upon one another, apparent size as seen from the earth, and many other points of interest to the admirers of the works of God. When that inquiry shall have been completed, we shall enter upon the consideration of those very beautiful and important results, which depend upon the rotation of the planets on their axes,—a species of motion to which we have not hitherto alluded.

We cannot better conclude this portion of our subject than by presenting the reader with the eloquent words of a pious and eminent divine, in connexion with the sublime subject which has thus far occupied us.

"The world in which we live, is a round ball of a determined magnitude, and occupies its own place in the firmament. But when we explore the unlimited tracts of that space which is everywhere around us, we meet with other balls of equal or superior magnitude, and from which our earth would either be invisible, or appear as small as any of those twinkling stars which are seen on the canopy of heaven. Why then suppose that this little spot, little at least in the immensity which surrounds it, should be the exclusive abode of life and intelligence? What reason to think that those mightier globes which roll in other parts of creation, and which we have discovered to be worlds in magnitude, are not also worlds in use and in dignity? Why should we think that the great Architect of nature, supreme in wisdom, as He is in power, would call these stately mansions into existence and leave them unoccupied? When we cast our eye over the broad sea, and look at the country on the other side, we see nothing but the blue land stretching obscurely over the distant horizon. We are too far away to perceive the richness of its scenery, or to hear the sound of its population. Why not extend this principle to the still more distant parts of the universe? What though, from this remote point of observation, we can see nothing but the naked roundness of yon planetary orbs? Are we therefore to say, that they are so many vast and unpeopled solitudes; that desolation reigns in every part of the universe but ours; that the whole energy of the Divine attributes is expended on one insignificant corner of these mighty works; and that to this earth alone belongs the bloom of vegetation, or the blessedness of life, or the dignity of rational and immortal existence?

"But this is not all. We have something more than the mere magnitude of the planets to allege in favour of the idea that they are inhabited. We know that this earth turns round upon itself; and we observe that all those celestial bodies which are accessible to such an observation, have the same movement. We know that the earth performs a yearly revolution round the sun; and we can detect, in all the planets which compose our system, a revolution of the same kind, and under the same circumstances. They have the same succession of day and night. They have the same agreeable vicissitude of the seasons. To them light and darkness succeed each other; and the gaiety of Summer is followed by the dreariness of Winter. To each of them the heavens present as varied and magnificent a spectacle; and this earth, the encompassing of which would require the labour of years from one of its puny inhabitants, is but one of the lesser lights which sparkle in their firmament. To them, as well as to us, has God divided the light from the darkness, and he has called the light day, and the darkness he has called night. He has said, let there be lights in the firmament of their heaven, to divide the day from the night; and let them be for signs, and for seasons, and for days, and for years; and let them be for lights in the firmament of heaven, to give light upon their earth; and it was so. And God has also made to them great lights. To all of them he has given the sun to rule the day; and to many of them has he given moons to rule the night. To them he has made the stars also. And God has set them in the firmament of heaven, to give light upon their earth, and to rule over the day, and over the night, and to divide the light from the darkness; and God has seen that it was good.

"In all these greater arrangements of Divine wisdom, we can see that God has done the same things for the accommodation of the planets that he has done for the earth which we inhabit. And shall we say, that the resemblance stops here because we are not in a situation to observe it? Shall we say, that this scene of magnificence has been called into being merely for the amusement of a few astronomers? Shall we measure the counsels of heaven by the narrow impotence of the human faculties? or conceive, that silence and solitude reign throughout the mighty empire of nature; that the greater part of creation is an empty parade; and that not a worshipper of the Divinity is to be found through the wide extent of yon vast and immeasurable regions?

"It lends a delightful confirmation to the argument, when, from the growing perfection of our instruments, we can discover a new point of resemblance between our Earth and the other bodies of the planetary system. It is now ascertained, not merely that all of them have their day and night, and that all of them have their vicissitudes of seasons, and that some of them have their moons to rule their night and alleviate the darkness of it; we can see of one that its surface rises into inequalities, that it swells into mountains and stretches into valleys; of another, that it is surrounded by an atmosphere which may support the respiration of animals; of a third, that clouds are formed and suspended over it, which may minister to it all the bloom and luxuriance of vegetation; and of a fourth, that a white colour spreads over its northern regions, as its Winter advances, and that, on the approach of Summer, this whiteness is dissipated, giving room to suppose, that the element of water abounds in it, that it rises by evaporation into its atmosphere, that it freezes upon the application of cold, that it is precipitated in the form of snow, that it covers the ground with a fleecy mantle, which melts away from the heat of a more vertical sun; and that other worlds bear a resemblance to our own, in the same yearly round of beneficent and interesting changes.

"Who shall assign a limit to the discoveries of future ages? Who can prescribe to science her boundaries, or restrain the active and insatiable curiosity of man within the circle of his present acquirements? We may guess with plausibility what we cannot anticipate with confidence. The day may yet be coming, when our instruments of observation shall be inconceivably more powerful. They may ascertain still more decisive points of resemblance. They may resolve the same question by the evidence of sense, which is now so abundantly convincing by the evidence of analogy. They may lay open to us the unquestionable vestiges of art, and industry, and intelligence. We may see Summer throwing its green mantle over these mighty tracts, and we may see them left naked and colourless after the flush of vegetation has disappeared. In the progress of years or of centuries, we may trace the hand of cultivation spreading a new aspect over some portion of a planetary surface. Perhaps some large city, the metropolis of a mighty empire, may expand into a visible spot by the powers of some future telescope. Perhaps the glass of some observer, in a distant age, may enable him to construct the map of another world, and to lay down the surface of it in all its minute and topical varieties. But there is no end of conjecture; and to the men of other times we leave the full assurance of what we can assert with the highest probability, that yon planetary orbs are so many worlds, that they teem with life, and that the mighty Being who presides in high authority over this scene of grandeur and astonishment, has there planted the worshippers of His glory."—CHALMERS, *Astronomical Discourses.*

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